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Story of an HRS sulfuric acid unit

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Abstract

Operational transformation gives us an opportunity to review our operation methods in a way to measure our performance and focus on a rational strategy to improve the PS3 plant productivity and reduce SO2 emissions.

This paper will detail specific process methodologies such as nondestructive process inspection (for example stick test provides operators with information about acid carryover in acid towers, operators can adjust acid and gas parameters depending on the result of the test and also to prepare spare parts for the next shutdown, another example is the pegasys test: pressure drop and conversion rate measurement of each catalyst bed helps operators optimizing the converter by adjusting the inlet temperature of each bed of catalyst). Other methodologies like process hazard analysis which addressed a cultural change into the team and also reinforced the relationship between operation and maintenance that's what leads us to reach a high level of performance.

We will present after how preventive maintenance has helped us to predict future failures in some strategic equipment such as gas heat exchanger, turbine, blower…etc. An intelligent design modification was also a key factor to improve the reliability of the entire PSIII sulfuric unit.

Our history can't be concluded without talking about overhaul schedules and planning. The capitalization of all best practices and procedures allows us to adapt and standardize our maintenance tasks and activities, in way to create our own systemic overhaul process, that includes mainly safety instructions and CND inspections and controls(vibration, thermography, Oil Analysis, Foucault current measurement, check-list controls for major and risky tasks…etc) adapted for each equipment with specific and detailed reports, and done by experienced and certified OCP Staff (for example ISO certification on vibration and thermography).

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Keywords: Sulfuric acid operation, pegasys test, inspection in sulfuric acid plant, HRS system.

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1. Introduction

PS3 is the first sulfuric acid plant with a heat recovery system(HRS) in OCP, this plant start up in 2000 with a capacity of 2300tpd (MECS-double absorption sulfur burning sulfuric acid plant). The environmental design was made to meet a value of 417ppmv SO_2 in stack gases and 0.075 kh H_2SO_4/MT H_2SO_4.

This article will highlight the main steps of the PS3 life, major troubleshooting and problems in the history of the plant and how we solve them. This paper will explain also the best practices of process control (stick test, pegasys test…etc), design changes in some equipment and their benefits, HRS operation and maintenance feedback, and we will explain how we achieve a 10% capacity increase after 15 years of operation with better performances (efficiency, SO_2 emissions, operating cycle).

Finally, we will present how preventive maintenance has helped us to predict future failures in some strategic equipment such as gas heat exchanger, turbine, blower…etc.

2. Important phases in the life of the plant

2.1 Start up

Before the start-up of the plant the operation team contributes actively in the review of the layout, PID's and PFD's of the plant. Adding a new technology like HRS in this plant gives a high motivation to all the team with a high experience in sulfuric acid operation and maintenance in single absorption process and scrubbing systems.

The first 5 years was a challenge to the team of this plant to understand the process, to be aligned with the design parameters. It was a success to operate a new technology that gives an opportunity to recover more energy from the sulfuric acid heat. The HRS system consists of a two stage packed heat recovery tower that absorbs SO_3 from the gas stream and recovers the heat from the absorption process as intermediate pressure stream, and a steam boiler that produces intermediate pressure steam (heat exchange between water and strong sulfuric acid) as shown in fig.1

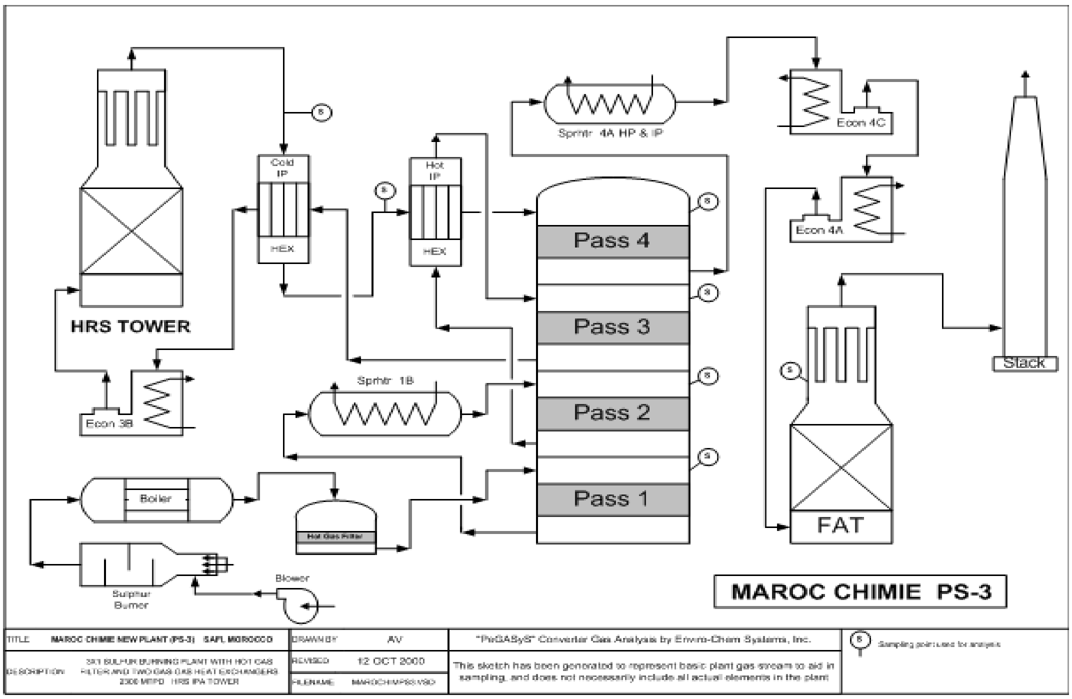

Fig. 1. Flow sheet of PS3 plant.

Many improvements in preheating and startup of the plant was done during the first years:

- The preheating with gasoil was designed first for 5 days, the initial heating should be carried out using dry air to minimize the water condensation on the catalyst: the review of the preheating procedure was done in a way that all passes reach a temperature between 100 and 170°C by a single dry blow instead of repetitive dry blows, it was possible because we preheat the sulfur burner to 1000°C for 4 hours. Then we preheat the converter until the exit temperatures of pass 1 and 4 of the converter are over 400°C and the inlet temperatures of all passes are over 400°C. Then we can feed the plant with sulfur. This new procedure reduces the time of preheating by 2 days.
- To control SO_2 emissions in the start-up of the plant a check-list was developed to control the critical parameters of the process:
  - ✓ Inlet and exit temperatures of all passes of the converter,
  - ✓ Dry and absorber acid concentration,
  - ✓ Dry and absorber flows
  - ✓ Dry air temperature
  - ✓ Inlet absorber gas temperature

Adding to this a day to day check of critical instruments (sulfur pressure, sulfur flow, acid flow, acid conductivity, and SO_2/O_2 analyzers). Without any change in the process and by only changing our methods and by training our operators we reduces the SO_2 pic in the start up by 30%, actually the SO_2 pic in startup phase doesn't exceed 500ppm.

The success of operating HRS more than 10 years without any major problems gives an opportunity to build new plants in OCP with this system (plant H in Maroc Phosphore I with a capacity of 3410 Tpd in 2011, JFC's plants in Jorf lasfar with a capacity of 4200 Tpd)

2.2 Major problems and Obstacles

The following are the major problems and obstacles for achieving a high level of performance in the plant:

- After 10 years of operating the cold gas exchanger between the intermediate plant and the 3rd pass of the converter (see Fig.2) has leakages and affect the performance of the plant.

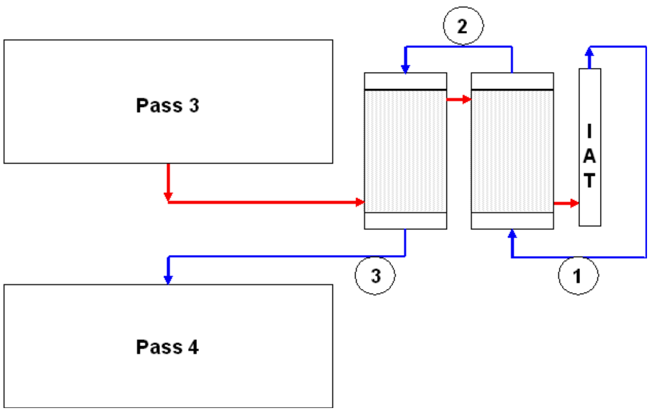

Fig. 2. Position of cold gaze changer in the process

The reaction of conversion of SO_2 to SO_3 in pass 4 was limited by SO_3 coming from the exit of pass3 through leakages in the cold gas exchanger (from point 2 to point 3 shown in the fig.2.). This problem affected the efficiency of the plant by 1.2% and as a result high SO_2 emissions in the stack.

To solve this problem a study was engaged to understand the phenomena and to find out the good solution.

As a result of the study it was a design problem: the gas coming from Intermediate tower absorption (stream 1 in Fig.2) has a temperature between 70 to 80°C, this temperature is ideal to have SO_2 and SO_3 condensation in the bottom of the cold gas exchanger that's why the lifecycle of this equipment is estimated between 7 to 11 years. It's a typical problem in double absorption towers. That was combined with hardware issues malfunctioning of first stage acid flow in HRS tower due to the severe condition of the circulating acid (High temperature about 218°C, and high concentration about 99.6%).

We opt for a solution that consists on changing the design of the cold gas heat exchanger by two points:

- Changing the material : using the stainless steel 316 instead of carbon steel
- Adding an internal by-pass for hot gas in the shell side of the exchanger in a way to keep the same temperature profile in the top and the bottom of the equipment to avoid SO_2 and SO_3 condensation
- Controlling carryover acid in the intermediate absorption tower by changing the flowmeter: using ultrasonic flowmeter in the first stage of HRS tower.

As a result of this solution and the combination with other actions like improving the sulfur quality (max.30ppm of ashes), and pneumatic screening of the catalyst (only 5% of lost), we achieve a high level of efficiency: 99.8% and 300ppmv of SO_2 in the stack at a rate of 110% after 22 months of continuous operating.

It's the very best performances achieved in 15 years of operating since the first start-up.

2.3 Nondestructive process control deployment

To maintain the performances achieved and to anticipate process deviation we deployed some nondestructive process controls:

Table 1. Nondestructive process control at PS3 plant

Control	***Consistence***	***Frequency***	***Recommendations***
Pressure drop	Pressure drop measurement in: Furnace, Boiler, Converter, acid tours, Heat exchangers, superheaters and economizers, mist eliminators	Once a week	Sulfur and air quality Air filter replacement Combustion parameters review SO2 concentration after combustion Instrument reliability Mist eliminator replacement Equipment cleaning and catalyst screening
Acid drain in dry and HRS tours	Follow acid drain quantities in dry and HRS tours	Once a day	Acid carryover Acid and gas parameters adjustment Acid distributor: leaks, alignment Mist eliminators
Stick test	Stick test for dry, intermediate and fin tours		
Pegasys Test	DT measurement and comparison with design DP measurement in each bed of converter Conversion rate of each bed Dew point in dry tour	Once a cycle	Converter parameters optmization Catalyst life cycle Catalyst screening Dry tour performance

2.4 Conversion optimization

The acid plant converter is the heart of the acid plant. In the converter, sulphur dioxide (SO_2) reacts with oxygen (O_2) in the presence of a catalyst to form sulphur trioxide (SO_3) according to the following reaction:

$$SO_2 + 1/2\ O_2 <=> SO_3$$

The converter serves the following functions:

- Provides single or multiple beds in which the catalyst is placed
- Provides for the distribution of gas across the catalyst bed.
- Provides for the collection of gas to exit the converter

The concept of optimization is to adjust the bed inlet temperature to maximize the temperature rise across the catalyst bed. This is generally a trial-and-error procedure.

As a result of multiples scenarios of changing inlet temperatures of each pass of the converter we obtain:

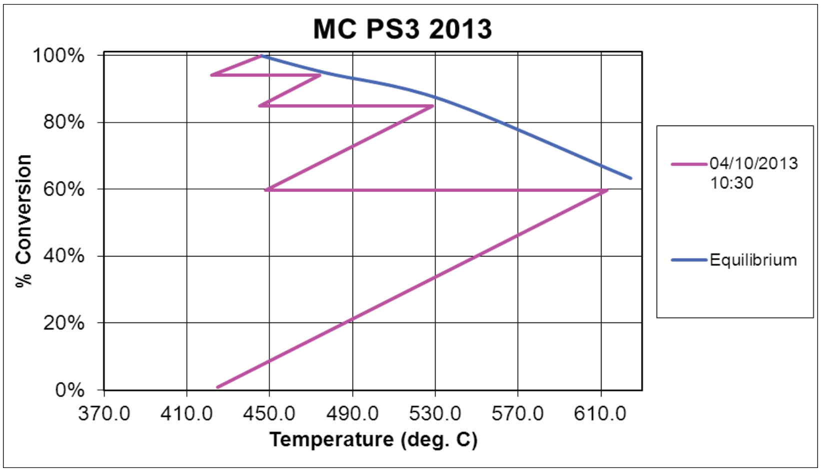

Fig. 3. Operation Vs equilibrium

The plant was running at about 110% of design capacity with catalyst that was screened 20 months before this sampling. Overall conversion was very good at 99.78%, only 0.01% from optimum and 0.06% from equilibrium.

2.5 Maintenance policy at PSIII

2.5.1 Preventive vs. Breakdown Maintenance

Everybody knows that preventive maintenance has long been recognized as extremely important in the reduction of maintenance costs and improvement of equipment reliability. In sulphuric acid plants, it takes many forms. Two major factors that should control the extent of a preventive program are; first, the cost of the program compared with the carefully measured reduction in total repair costs and improved equipment performance; second, the utilization percentage of the equipment maintained. If the cost of planning a preventive-maintenance inspection has essentially the same as the cost of repair after a failure accompanied by preventive inspections, the justification is weak. On the other hand, if the breakdown could result in severe damage to the equipment and a far more costly repair, the scheduled inspection time should be considered and strictly followed. Furthermore, in sulphuric acid plants, maintenance should be tailored to fit the function and specificities of different items of equipment (pumps, tanks, coolers, towers…etc) rather than applied in the same manner to all equipment.

To make a good periodic cold shutdown in a sulphuric acid plant, we must at first realize all inspections to identify with precision all tasks required for each equipment, if the inspections are not professionally done, or for lack of resources is incompletely realized, we risk to start up the unit after overhaul and have several breakdowns just after. To avoid this problem and make our preventive maintenance successful, we must always bear in mind that sulfuric acid plants must stop just in periodic overhaul and not due to breakdowns.

Fig. 4. Inspection analysis: oil analysis, thermography, vibration

One of the most effective methods of tempering ideal preventive maintenance in sulphuric acid plants, with practical considerations of a continuous operation, is to take advantage of a breakdown in some component of the line to perform vital inspections and replacements which can be accomplished in about the same time as the primary repair. This requires recording the deficiencies observed during operating inspections and moving in quickly with craftsmen and supervision prepared to work until the job is done. Production supervision can usually be sold on the need for a few more hours' time for additional work in a repair of a breakdown, much more easily than they can be convinced of its necessity when things are apparently running smoothly.

3. Conclusion

To be efficient and achieve a great result, maintenance and production must work together and have a common goal to focus their energy in the same direction. That's the unique way to produce sulphuric acid with less effort. The results take time to appear, but when they appear based on solid support and rigor, they will sustain for a long time.

References

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